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Local Jordanian Materials to Produce a Bakelite-base Construction Composite Material

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ABSTRACT

In this investigation, a combined experimental approach of micro-structural observation and compressive load capacity testing were followed to determine the behavior of bakelite matrix material reinforced with Jordanian silica sand. It was found that the reinforced samples gave a higher maximum load capacity than the pure matrix, because the homogeneous structure helped in distributing the applied load between the matrix and the reinforcement. Moreover, the higher the volume fraction of the reinforcement, the higher the maximum load capacity of the composite. The maximum load capacity of the samples with 75% content of Jordanian silica sand was less than that of pure bakelite. On the other hand, the higher the particle size of the reinforcement, the higher the maximum load capacity of the composite. Composites of bakelite matrix gave a higher maximum load capacity than that of polystyrene matrix. In addition, a longitudinal brittle fracture was observed for the composites.

KEYWORDS: Silica sand, Load capacity, Composite, Reinforcement, Matrix.

INTRODUCTION

Profound changes in industrial and construction materials over the past ten years provide a classic example to follow in other fields of technical progress, particularly in composite materials (Green, 1987). Polymer Matrix Composites (PMCs) are among the best established advanced and engineering composite materials. The three classes of polymers; namely thermoplastics, thermosets and rubbers, are all employed as matrices. As far as mechanical properties are concerned, their stiffness and strength could be dramatically improved by reinforcement (Jalham, 1999; Al-Momany and Jalham, 1999). Moreover, in composite materials, a complex and contradictory problem has been solved; i.e. an increase in output with a reduction in total production cost (Peterson, 1982). Sand has always been and will remain for the foreseeable future, the main building material (Jacobs et al., 1981). A study which was conducted by the Royal Scientific Society (RSS) on local materials reported that 40% of Jordan's total area is covered by silica sand and is usable for molding processes and other applications without any grading or further processing (Khrais et al., 1993). Previously, Jalham in his works (1999, 2003, 2004 and 2005) studied the polystyrene as a matrix material for Jordanian silica sand. Sound results were obtained regarding the improvement of strength, wear resistance and other properties. As thermo-sets generally has better promising mechanical properties than

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thermoplastics, it was decided to study the properties of the reinforced bakelite with Jordanian silica sand of different particle sizes (60, 75 and 85 μm) and different percentages (0, 25, 50 and 75 wt %). Jordanian Portland cement was used as a bonding material in the amount of 1/6 of the weight of silica sand. The testing specimen were manufactured and tested under compression loading in the Industrial Engineering Department at the University of Jordan as a part of a large study on local materials. A comparison of the results of this composite with the polystyrene matrix composite is of great importance. The objective of this work is to design a new construction material by utilizing local resources and finding the best combination of matrix and reinforcement materials that give the maximum strength.

Table 1: The chemical composition of the Jordanian silica sand

SiO_2 %	***Na_2O %***	***K_2O %***	***CaO%***	***MgO %***	***Fe_2O_3 %***	***Al_2O_3 %***
97.65	0.01	0.02	0.01	0.02	0.66	0.85

Table 2: Maximum load capacity of the samples based on sand percent and particle size for bakelite matrix composites

Content of Jordanian Silica Sand (%)	***Particle Size of Jordanian Silica Sand (μ m)***	***Maximum Load Capacity (kN)***
5	60	109.20
	75	126.01
	85	139.65
25	60	140.56
	75	159.80
	85	176.8
50	60	189.60
	75	207.14
	85	223.10
75	85	103.39
0	-	106.56

MATERIALS

1. ***Jordan Silica Sand****:* this study was carried out on relatively fine natural sand of different size distributions as mentioned earlier. The chemical composition of this sand is shown in Table 1.
2. ***Jordan Portland Cement****:* A Portland Pozzolana Cement 'case A' strength class 42.5 complying with Jordanian Standard JS/219/1993 was used as a binding material.
3. ***Bakelite*****:** It is the trade name of phenol-formaldehyde or phenolic resins (first totally synthetic plastic). Its applications comprise insulation of electrical apparatus (since it is a nonconductor), manufacture of certain machinery gears and making handles and spare parts of daily household articles. Moreover, a lot of colors are available: black, red, green, orange, brown, yellow and blue.

EQUIPMENT

The main equipment used in this project are:

1. *Denver instrument (laboratory balance).* This instrument was used to weigh the samples with accuracy of 0.01 mg.

Table 3: Maximum load capacity of the samples based on sand percent and particle size for polystyrene matrix composites as repoted in (Jalham, 1999)

Content of Jordanian Silica Sand (%)	*Particle Size of Jordanian Silica Sand (μm)*	*Maximum Load Capacity (kN)*
5	60	46.32
25	60	53.60
50	60	63.53
	75	65.05
	85	67.47
75	85	43.01
0	-	43.68

Figure 1: Mounting press machine of METASERV type

Figure 2: Compression testing machine of ELE type

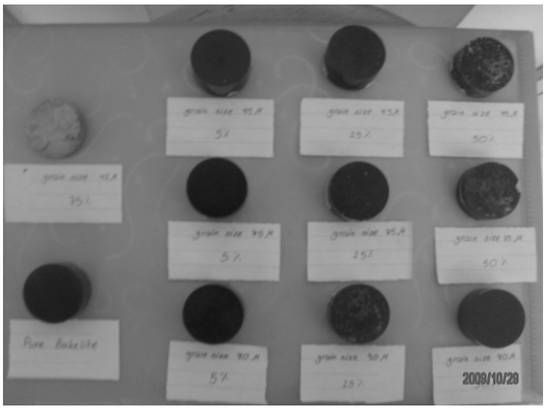

Figure 3: The representative samples for each variable

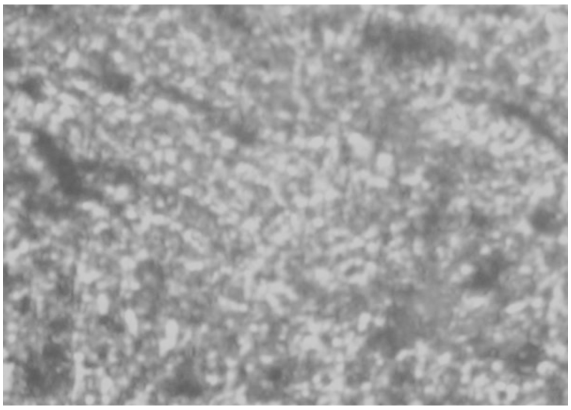

Figure 4: The distribution of sand particles inside the matrix

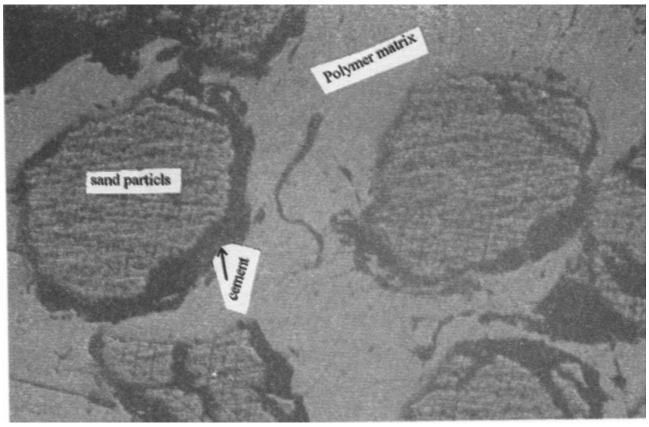

Figure 5: Bonding between sand, cement and bakelite

Figure 6: The longitudinal fracture of the pure matrix

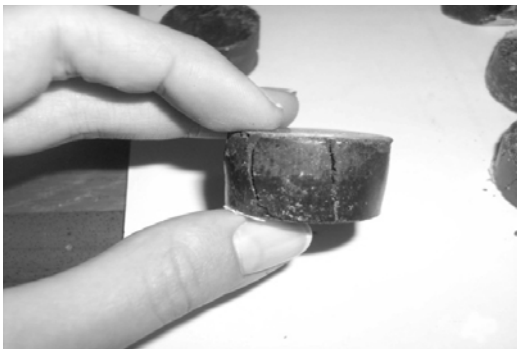

Figure 7: The longitudinal fracture of the composite

2. *Mounting machine of type METASERV (Figure 1):* This machine provided us with the necessary temperature and pressure to form cylindrical specimens of 30 mm diameter and 17 mm height.
3. *Compression testing machine :* This machine is shown in Figure 2. It is of the type (ELE) and used to record the maximum load that each specimen can hold.
4. *Electric shaker:* Single phase, 220/240 V, 50 Hz, manufactured by Pascal Engineering Co., Ltd.
5. *Grinder/polisher machine:* This machine is of BUEHLER type and used for grinding and polishing processes.
6. *Optical microscope* This microscope is of (MEIJI) type and used for testing the microstructure of the specimens.

PROCEDURE

The above-mentioned materials were mixed in the mixing pan with different proportions of bakelite, silica sand and cement. The mixing proportions were based on weight. The mean particle sizes were 60, 75 and 85 μm while the weight percentages were 0, 25, 50 and 75 wt %. The cement weight was 1/6 of the weight of the sand. The balance weight was that of bakelite. It is worth mentioning that the particle size was controlled by sieving the sand through sieves of different hole sizes by shaking them on the above-mentioned shaker. The sand was then washed and dried in furnace for 24 hours at 100°C. The mixture was then cast into the cylindrical chamber of the mounting machine and a constant pressure of 5.5 bar was applied to the mixture at a constant temperature of 180 °C for 15 minutes. Three samples for each level were manufactured, because of the limited supply of the polystyrene raw material. Then the product was cooled and tested under compression on the ELE type compression machine to determine the maximum load capacity of the specimens.

The microstructure test of the specimens was conducted to examine the homogeneity of the particles' distribution inside the matrix. The testing of the microstructure started from the grinding of the specimen using SiC papers of 500, 800, 1200 and 2400 μ m at a speed of 300 rpm and with water as a lubricant and ending with polishing using a pad with diamond paste of 3μ m at 150 rpm with blue lubricant (Jalham, 2010).

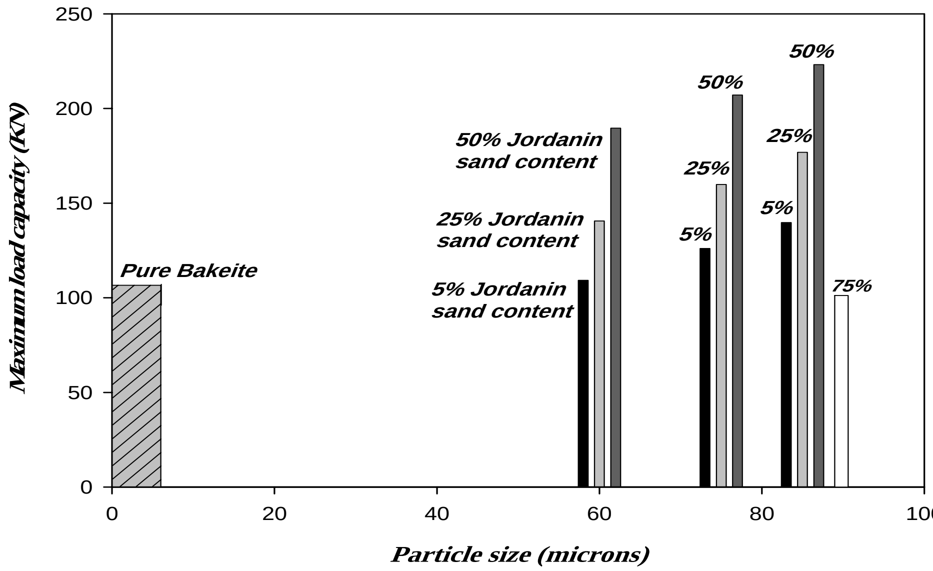

Figure 8: Load capacity for the specimens based on Jordanian sand contents and particle sizes

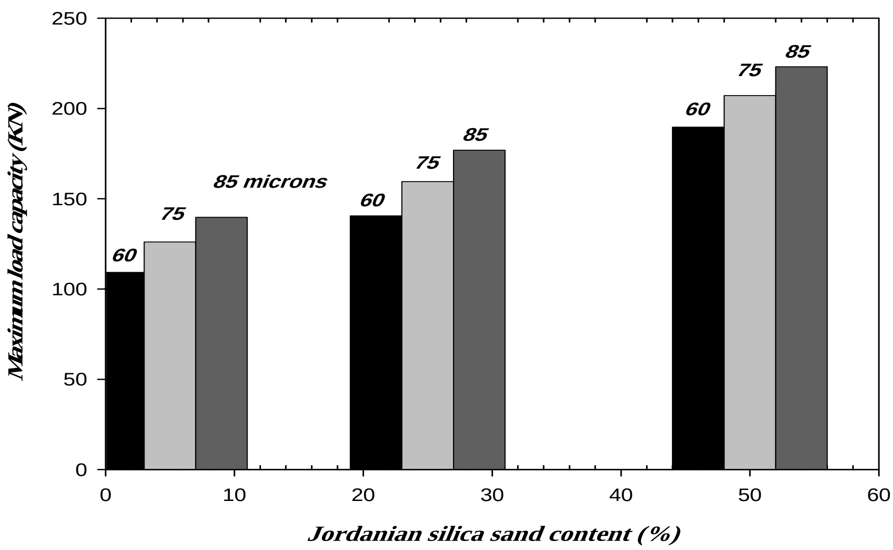

Figure 9: Load capacity for the specimens based on Jordanian sand contents 5, 25 and 50% and different particle sizes

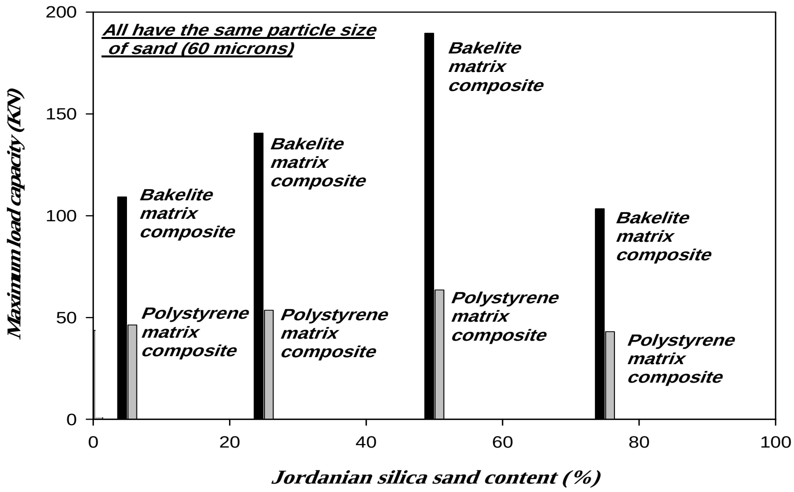

Figure 10: Comparison between composites of polystyrene matrix and bakelite matrix reinforced with Jordanian silica sand of different percentages (5, 25, 50 and 75%) and 60 micron particle size

RESULTS

30 specimens were manufactured to end up with reliable results. The mean value of the three specimens for each level was taken. Representative 10 samples (one for each level in addition to the one of pure bakelite) are shown in Figure 3. The main results of this investigation can be summarized as follows:

The microstructure: The microstructure after polishing is shown in Figures 4 and 5. Figure 4 indicates that the distribution of sand particles inside the matrix is homogeneous and Figure 5 shows that good bonding has occurred between sand, cement and bakelite.

The maximum load capacity test: The mean maximum load capacity of the specimens is shown in Table 2. It is clear that the higher the percent of the reinforcement, the higher the ultimate strength except for the 75% of reinforcement which was the lowest. On the other hand, the same table shows that the higher the particle size, the higher the strength.

Moreover, the deformation test was carried out until fracture. A longitudinal fracture was observed for the pure matrix (Figure 6) and for the composite (Figure 7).

DISCUSSION

The properties of materials not only depended upon the physical and chemical properties of constituents, but also on the physical conditions prevalent at the time of mixing and testing of the specimens (Zhang, 1990). Therefore, in order to ensure consistent quality of the specimens, which gives a confidence in the method of manufacturing used in this investigation, a micro-structural investigation was carried out by following the common procedure of grinding and polishing of the specimens (Jalham, 2010). The mixing method showed successful results as can be concluded from the good distribution of particles shown in the microphotograph in Figure 4. Regardless the percentage of bakelite, a good bonding between the silica sand and the bakelite was found with the help of cement as shown in the photograph in Figure 5. The photographs of the fractured specimens showed a longitudinal type of fracture for both the pure material (Figure 6) and the composite (Figure 7). This is in agreement with the results obtained by Jalham (1999). Systematic testing of materials is an inseparable part of any quality control program, which helps achieve a higher efficiency of the material used and a greater assurance of the performance with regard to both strength and durability (Gutierrez, 1996). In this respect, experimental investigations of compressive strength using the ELE compression testing machine were carried out on the samples with different mixture proportions of bakelite to determine the maximum load capacity of the material. As for any other types of particulate reinforcements, the sand particulate size and volume fraction influence the strength of the composite. It is clear from Figure 8 that the increase in the sand volume fraction enhances the strength of the low strength matrix, which is shown by the 0% bar in the same figure. The increase in strength was due to the load transfer among the particles of the composite and the good bonding. This behavior is in agreement with the results obtained by Jalham (1999) when the polyamide-6 (PA-6) and polyamide-11 (PA-11) were reinforced with different volume fractions of poly 4-hydroxybenzonate (PHB) (Taesler et al., 1996). It is also worth mentioning that this is in agreement with the behavior of metal matrix composites (Lloyd, 1988; Barlow, 1991; Llorcaetal., 1992).

An important and interesting behavior was observed when the reinforcement was 75% as shown in (Figure 8). It is clear that the strength dropped lower than the strength of the matrix. The reason for this behavior is that the bakelite particles that exist in the spaces between the sand particles, especially those away from the surface towards the center, were not affected by the forming temperature because of the bad heat conductivity of the silica sand and cement. In this case, there was neither a bonding inside the specimen nor a load transfer among the particles.

The grain size influenced the ultimate strength as well. This is clear from Figure 9. The larger the grain size, the higher the ultimate strength of the composite. This can be explained in that the greater the particle size, the more space between the particles of sand which helps in the existence of more cement (bonding material) and more bakelite particles, which enhances the bonding and makes the transfer of the load more reliable. These results are in contrast with the behavior of metals as in metal matrix composites, where the finer the grain size, the stronger the composite (Hunt et al., 1991).

The results obtained by Jalham (1999) for the polystyrene matrix reinforced with different percentages of Jordanian silica sand are presented in Table 3 for the purpose of comparison. Figure 10 shows the comparison between the polystyrene matrix composites and the bakelite matrix composites. It is clear from this figure that pure bakelite is stronger than pure polystyrene which was reflected on the results of the composites of bakelite matrix composites. There is also an agreement in the results for the 75% content of sand.

It was observed that the fracture is longitudinal for the matrix material (Figure 6) as well as for the composite (Figure 7), but the fracture of the composite is of the brittle type.

CONCLUSIONS

The main conclusions of this investigation are:

1. The mixing and manufacturing method helped in achieving a homogeneous distribution of sand particles in the bakelite matrix.
2. The reinforced samples gave a higher maximum load capacity than the pure matrix, because the homogeneous structure helped in distributing the applied load between the matrix and the reinforcement.
3. The maximum load capacity of the samples that contain 75% content of Jordanian silica sand was less than that of pure bakelite.
4. The higher the volume fraction of the reinforcement, the higher the maximum load capacity of the composite
5. The higher the particle size of the reinforcement, the higher the maximum load capacity of the composite.
6. Composites of bakelite matrix gave a higher maximum load capacity than those of polystyrene matrix.

REFERENCES

Ayman H. Almomany and Issam S. Jalham. 1999. A new potential of sand for industry, *Emirates Journal for Engineering Research*, 4 (1): 32-36.

Barlow, C.Y. 1991. Metal matrix composites. Proc. of the 12th International Symposium, Ed. Hansen, N. et al., 1-15, Roskilde, Denmark: International Laboratory.

Green, A. 1987. Glass-fiber-reinforced composite in building construction. *Transportation Research Record*, 1118.

Gutierrez, Pilar A. and Canovas, Manuel F. 1996. High-performance concrete: requirements for constituent materials and mix proportioning, *J. of the American Concrete Institute*, 93 (3): 233-241.

Hunt, W.H., J.R. Brockenbrough and P.E. Magnusen. 1991. Scripta Metallurgica. *Mater*., 25: 15.

Issam S. Jalham. 2010. Experimental laboratory manual in materials science and enginreering, 2nd edition (revised and modified), Publications of the University of Jordan, Deanship of Academic Research.

Issam S. Jalham. 1999. Jordanian silica sand and cement as a reinforcement material for polystyrene matrix composites, *Dirasat: Engineering Sciences*, 26 (2): 241-250.

Issam S. Jalham. 2004. The effect of processing and material parameters on the shrinkage of polystyrene matrix reinforced with silica sand and cement, *Dirasat: Engineering Sciences*, 31 (1): 118-125.

Issam S. Jalham. 2003. The influence of processing and material parameters on the compressive load capacity of polystyrene matrix reinforced with Jordanian silica sand, *Emirates Journal for Engineering Research (EJER)*, 8 (2): 21-24.

Jacobs, M.J.N. and Forton. 1981. Polymer glass reinforced cement: a many sided construction material. *Proceedings of the International Congress*, GFRC, Paris.

Khraise, Rami E., Al-Omary, Basim and Melhem, Osama A. 1993. Sand moulding manual, Royal Scientific Society, Amman - Jordan.

Llorca, J., S. Surresh and Needleman. 1992. *Mater. Trans.*, 23A, 9/9.

Lloyd, D.J. 1988. Metal matrix composite: an overview, *Proc. of International Symposium on Advanced Structural Material*, Ed.: P. S. Wilkinnson.

Peterson, K. A. 1982. Silicon as a mechanical material, *TIIAR*, 70 (5).

Taesler, Chr., H. Wittich, C. Juergens, K. Sculte and H.R. Kricheldorf. 1996. *J. of Applied Polymer Science*, 61: 783.

Zhang, M.H. and Gjorv, O.E. 1990. Microstructure of the interfacial zone between lightweight aggregate and cement paste. *Cement and Concrete Research*, 20: 610-618.